The Impact of Point-of-Care Ultrasound-Guided Resuscitation on Clinical Outcomes in Patients With Shock: A Systematic Review and Meta-Analysis

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

John Basmaji, MD[1]
Robert Arntfield, MD[1]
Karishma Desai, MD[1]
Vincent I. Lau, MD, MSc[2]
Kim Lewis, MD, MSc[3,4]
Bram Rochwerg, MD, MSc[3,4]
Kyle Fiorini, MD[1]
Kimia Honarmand, MD, MSc[5]
Marat Slessarev, MD, PhD[1]
Aleks Leligdowicz, MD, PhD[1]
Brian Park, BSc[1]
Ross Prager, MD[1]
Michelle Y.S. Wong, MSc[1]
Philip M. Jones, MD, MSc[6]
Ian M. Ball, MD, MSc[1]
Nicolas Orozco, MD[7,8]
Maureen Meade, MD, MSc[4]
Lehana Thabane, PhD[4]
Gordon Guyatt, MD, PhD[4]

OBJECTIVE: To determine the impact of point-of-care ultrasound (POCUS)-guided resuscitation on clinical outcomes in adult patients with shock.

DATA SOURCE: We searched MEDLINE, Embase, and unpublished sources from inception to December 2023.

STUDY SELECTION: We included randomized controlled trials (RCTs) that examined the use of POCUS to guide resuscitation in patients with shock.

DATA EXTRACTION: We collected data regarding study and patient characteristics, POCUS protocol, control group interventions, and outcomes.

DATA SYNTHESIS: We identified 18 eligible RCTs. POCUS slightly influences physicians' plans for IV fluid (IVF) and vasoactive medication prescription (moderate certainty), but results in little to no changes in the administration of IVF (low to high certainty) or inotropes (high certainty). POCUS may result in no change in the number of CT scans performed (low certainty) but probably reduces the number of diagnostic echocardiograms performed (moderate certainty). POCUS-guided resuscitation probably reduces 28-day mortality (relative risk [RR] 0.88; 95% CI, 0.78–0.99), the duration of vasoactive medication (mean difference −0.73 d; 95% CI, −1.16 to −0.30), and the need for renal replacement therapy (RRT) (RR 0.80; 95% CI, 0.63–1.02) (low to moderate certainty evidence), and lactate clearance (high certainty evidence). POCUS-guided resuscitation may results in little to no difference in ICU or hospital admissions, ICU and hospital length of stay, and the need for mechanical ventilation (MV) (low to moderate certainty evidence). There is an uncertain effect on the risk of acute kidney injury and the duration of MV or RRT (very low certainty evidence).

CONCLUSIONS: POCUS-guided resuscitation in shock may yield important patient and health system benefits. Due to lack of sufficient evidence, we were unable to explore how the thresholds of operator competency, frequency, and timing of POCUS scans impact patient outcomes.

KEYWORDS: critical care; hemodynamics; point-of-care testing; shock; ultrasonography

Due to the need for simultaneous diagnosis and dynamic intervention, shock management presents a formidable challenge in acute care settings. Furthermore, time-sensitive clinical decisions made under duress in patients with shock have a narrow margin for error. To address the complexities of shock management, physicians rely on hemodynamic tools to guide resuscitation decisions (1).

Point-of-care ultrasound (POCUS) has gained widespread adoption by acute care physicians, given its potential to improve the diagnosis and management

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

DOI: 10.1097/CCM.0000000000006399

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

SHOUT
SHARE
IT

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

KEY POINTS

Question: What is the therapeutic impact of point-of-care ultrasound (POCUS) for changing physician management, resuscitative therapies and diagnostic tests, and clinical outcomes in patients with shock?

Findings: In this meta-analysis, POCUS, when used to resuscitate patients with shock, influenced physician management, reduced the need for certain diagnostic tests, improved lactate clearance, and likely reduced the duration of vasoactive medication, need for renal replacement therapy, and mortality at 28 days.

Meaning: Using POCUS to guide the resuscitation of patients in shock may yield important patient and health system benefits.

of shock (2). Clinicians may use POCUS to assess how patients respond to changes in management in real-time, guide vasoactive medication administration, determine the need for other diagnostic tests, and reveal actionable pathology (e.g., cardiac tamponade) amenable to potentially life-saving intervention. POCUS can also evaluate multiple organ systems affected by shock (e.g., heart, lungs, abdomen, and circulatory system) and provide a broader understanding of the patient's physiology. Finally, POCUS is painless, radiation-free, and poses a low risk of adverse events. With ultrasound technology already embedded in acute care medicine for focused assessments of trauma patients and procedural guidance, POCUS is well positioned as a promising tool for shock management.

Despite these theoretical benefits, the impact of POCUS on patient-important outcomes remains uncertain. As POCUS use becomes more widespread and incorporated into educational curricula across various disciplines, there exists a pressing need to address the impact of POCUS on patient management decisions, healthcare utilization, and patient-important outcomes. To address this knowledge gap, we undertook a systematic review summarizing the impact of POCUS-guided resuscitation in critically ill patients with shock across a hierarchy of outcomes (3), consolidated existing knowledge for POCUS, and identified areas for further research.

MATERIALS AND METHODS

We followed the Cochrane Handbook for Systematic Reviews and Interventions and reported results according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (www.prisma-statement.org) (**eAppendix 1**, http://links.lww.com/CCM/H577) (4). We registered the protocol before data extraction (PROSPERO ID: CRD4202016000). **eAppendix 2** (http://links.lww.com/CCM/H577) summarizes post hoc protocol changes and the rationale.

Search Question, Population, Inclusion, and Exclusion Criteria

This review compared the impact of POCUS-guided resuscitation versus no POCUS-guided resuscitation or usual care on modification of therapy and outcomes of patients in shock. We included studies enrolling adult patients with shock or systolic hypotension (e.g., systolic blood pressure < 100 mm Hg) secondary to any cause. Eligible studies had to evaluate POCUS-guided resuscitation. We define POCUS as the acquisition, interpretation, and immediate clinical integration of ultrasound applied at the bedside by a treating clinician to inform management decisions, such as intervening on underlying shock etiology (e.g., pericardial effusion, clot in the right ventricle), administration of vasoactive medications (e.g., identifying global systolic dysfunction), or fluid administration (through determining fluid responsiveness and fluid tolerance). POCUS can encompass a variety of organ systems (heart, lungs, blood vessels, and abdominal structures), different modalities for assessment (transesophageal or transthoracic/transabdominal), and a spectrum of risk that ranges from virtually no risk for surface ultrasound modalities to low risk for transesophageal modalities. Anticipating the heterogeneity of practice patterns, we did not specify a priori criteria for the comprehensiveness, user competence, timing, and frequency of POCUS scans performed. Eligible studies had to compare shock management in patients receiving POCUS to management without POCUS, including any other forms of guided therapy or usual care. We included all randomized controlled trials (RCTs), including pilot feasibility studies, that met our population, intervention, comparison, and

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

outcomes criteria. Finally, we also included cohort studies with a control arm and "before-after" studies in which patients served as their own controls. We excluded scoping reviews, systematic reviews, experimental/animal studies, meta-analyses, and nonresearch articles; however, we screened references to identify other eligible studies.

We evaluated POCUS across a hierarchy of outcomes. First, we evaluated the impact of POCUS on the therapeutic decision-making of healthcare providers (e.g., whether POCUS changed physicians' decision to administer IVF, alter vasoactive medications, or plans for diagnostic tests). Second, we evaluated whether POCUS resulted in a difference in the resuscitative therapies administered to the patient (e.g., total volume of IV fluid [IVF] at 6, 24, and 72 hr, vasoactive medications administered to patients, and diagnostic studies performed). Third, we evaluated the effect of POCUS on patient-important outcomes, including mortality, ICU or hospital admission (in the subset of patients treated in the emergency department) and length of stay, provision and duration of organ-sustaining therapy (e.g., mechanical ventilation [MV], renal replacement therapy [RRT], and vasoactive medications), and organ injury (e.g., acute kidney injury [AKI]).

Search Strategy

Guided by a health information specialist (A.I.), we performed searches in MEDLINE, Embase, and the gray literature up until December 2023. We did not restrict the search by language and included the following terms: point-of-care ultrasound, echocardiography, shock, and hypotension. **eAppendix 3** (http://links.lww.com/CCM/H577) presents the final search strategy.

Study Selection

We used Covidence software for screening articles in two stages. Two reviewers (J.B. and K.D.) independently reviewed titles and abstracts and identified possibly eligible articles for full-text review. In the second stage, we reviewed full texts of any citation deemed potentially eligible in the title and abstract screening. A third reviewer (V.L.) resolved disagreements in the first and second stages.

Data Extraction

Using a piloted standardized form, two reviewers (J.B. and K.D.) extracted data independently and in duplicate. We extracted the study design, number of patients, characteristics of POCUS scans and controls, and relevant outcome data. Reviewers resolved disagreements by discussion. If required, a third party (V.L.) arbitrated disagreements. For missing outcome data, we contacted authors every 2–4 weeks up to three times.

Data Analysis

We used RevMan (version 5.3; Cochrane Collaboration, Oxford) for meta-analysis, which was conducted using inverse variance random-effects models. For continuous outcomes, we converted medians into means, and interquartile ranges into SDs. When SD data were missing, we used *p* values or pooled SD estimates from other studies in this review to impute missing data.

We present continuous outcomes as mean differences (MDs), dichotomous outcomes as risk differences (RD), and risk ratios (RRs) with associated 95% CIs. We assessed for statistical heterogeneity using visual inspection of forest plots, the chi-square test for homogeneity, and I^2 statistic. We evaluated publication bias by visual inspection of forest plots and Egger's test for outcomes with more than 10 RCTs. We made a post hoc decision to conduct subgroup analysis based on the POCUS protocol used. After discussion, team members classified POCUS protocols as those that used transthoracic cardiac evaluations (e.g., cardiac scans alone, cardiac and lungs, or cardiac, lungs, and vessels combined), transesophageal cardiac evaluation, inferior vena cava evaluation only, or a lung evaluation only. We explored whether a subgroup effect was due to the risk of bias or if the POCUS protocol explained important heterogeneity. For any subgroup effect that was found to be potentially significant (interaction $p < 0.1$), we used Instrument to assess the Credibility of Effect Modification Analyses (ICEMAN) criteria to evaluate its credibility (4).

Risk of Bias and Rating Certainty of the Evidence

We used the Cochrane Risk of Bias (Version 2.0; randomized trials) (5) tool to assess the risk of bias and

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

rated the certainty of the evidence using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system (6). RCTs started as high certainty evidence with opportunities to rate down certainty if there were limitations in risk of bias, imprecision, inconsistency, or indirectness. For clinical outcomes, resuscitative therapies, and diagnostic tests, we rated our certainty in the smallest difference that patients and healthcare systems would experience as important; team members decided on thresholds through discussion. For outcomes pertaining to lactate clearance and changes to clinician decision-making, we rated the certainty of whether a non-null effect was present. **Table 1** provides a summary of these thresholds. We intended to report evidence from nonrandomized studies (NRS) when they provided complementary or sequential evidence and when evidence from RCTs was of low certainty. However, we did not use NRS because they did not enhance the evidence from RCTs.

RESULTS

Of the initial 8536 citations, we evaluated 261 full-text articles and included 18 RCTs (**Fig. 1**) (7–24). We contacted six authors and four provided missing outcome data and/or clarified results for eligible studies. Most of the included studies enrolled ICU patients with shock from any cause (**eTable 1**, http://links.lww.com/CCM/H577), implemented POCUS protocols including at least a cardiovascular evaluation and did not report the operator characteristics, frequency, or timing of POCUS evaluations (**eTable 2**, http://links.lww.com/CCM/H577). In studies that reported operator characteristics, independently licensed physicians with formal training in POCUS completed the scans (eTable 2, http://links.lww.com/CCM/H577). We judged most eligible studies to be at low risk of bias (**eTable 3**, http://links.lww.com/CCM/H577) and outcomes to be at low risk of publication bias. We summarize the findings for the impact of POCUS-guided resuscitation on clinician decision-making in **Table 2**, resuscitative therapies and diagnostic tests in **Table 3**, and clinical outcomes in **Table 4**.

Impact on Clinician Decision-Making

POCUS-guided resuscitation probably results in slightly fewer changes to the IVF prescription during the first 72 hours of resuscitation (0.6 fewer changes per patient; 95% CI, 0.91 fewer–0.29 fewer, moderate certainty) (17). Furthermore, POCUS probably results in slightly fewer changes to the escalation of inotrope prescriptions (0.4 fewer changes per patient; 95% CI, 0.54 fewer–0.26 fewer, moderate certainty) and vasopressors (0.10 fewer changes per patient; 95% CI, 0.17 fewer–0.03 fewer, moderate certainty).

Impact on Resuscitative Therapies and Diagnostic Tests

POCUS-guided resuscitation may result in little to no difference in the volume of IVF administered at 6 hours (0.39 L less; 95% 0.65 L less–0.14 L less, low certainty; **eFig. 1**, http://links.lww.com/CCM/H577) (8, 9, 12, 16, 18, 21, 23), 24 hours (0.62 L less; 95% CI, 0.89 L less–0.35 L less, high certainty; **eFig. 2**, http://links.lww.com/CCM/H577) (7, 11–14, 16, 18, 19, 21, 23, 24), and at 72 hours (0.18L less; 95% CI, 0.68 L less–0.31 L more, moderate certainty; **eFig. 3**, http://links.lww.com/CCM/H577) of resuscitation (16–18). We did not find any evidence of credible subgroup effects (**eTable 4**, http://links.lww.com/CCM/H577) for IVF administration.

POCUS-guided resuscitation may result in little to no effect on inotrope administration (RR 0.99; 95% CI, 0.84–1.17; RD 1.5%, high certainty; **eFig. 4**, http://links.lww.com/CCM/H577) (8, 9, 14, 16, 17, 21). The authors reported that inotrope administration during study intervention periods spanned from 6 to 72 hours.

POCUS may have little to no effect on the number of CT scans performed (RR 1.10; 95% CI, 0.73–1.66; RD 2.4%, low certainty). However, POCUS probably reduces the number of diagnostic transthoracic echocardiograms (TTE) performed (RR 0.74; 95% CI, 0.57–0.96; RD –9.2%, moderate certainty). Of note, data on the number of TTE performed came from a study that used continuous transesophageal monitoring using the hemodynamic TEE device (ImaCor Inc, Garden City, NY).

Impact on Clinical Outcomes

Surrogate Clinical Outcomes for Shock Resolution. POCUS-guided resuscitation results in a trivial difference in lactate clearance at 6 hours (MD of 7.07%; 95% CI, 0.13–14.02; high certainty; **eFig. 5**, http://links.lww.com/CCM/H577) (7, 10, 12, 16, 18, 23) and

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

TABLE 1.
Certainty Targets for Outcomes

Outcome Hierarchy	Outcomes	Certainty Target
Mortality	28-d mortality	Difference of 5/1000
ICU and hospital utilization	ICU admission	Difference of 50/1000
	ICU length of stay	Difference of 1 d
	Hospital admission	Difference of 50/1000
	Hospital length of stay	Difference of 1 d
Organ sustaining therapies	Provision of mechanical ventilation	Difference of 50/1000
	Duration of mechanical ventilation	Difference of 0.5 d
	Duration of vasoactive medication	Difference of 0.5 d
	Provision of renal replacement therapy	Difference of 10/1000
	Duration of renal replacement therapy	Difference of 1 d
Surrogate clinical outcomes	Acute kidney injury	Difference of 50/1000
	Lactate clearance rate at 6 hr	Non-null effect
	Lactate clearance rate at 24 hr	Non-null effect
Administration of resuscitative therapies and diagnostic tests	IVF administration at 6 hr	Difference of 0. 5 L
	IVF administration at 24 hr	Difference of 1 L
	IVF administration at 72 hr	Difference of 2 L
	Inotrope administration	Difference of 50/1000
	Diagnostic CT scans performed	Difference of 10 fewer/1000
	Diagnostic transthoracic echocardiograms performed	Difference of 25 fewer/1000
Changes in physician management	Changes to IVF prescription	Non-null effect
	Changes to inotrope or vasopressor medication prescription	Non-null effect

IVF = IV fluid.

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

24 hours (MD 15.40%; 95% 3.4–27.4, high certainty; **eFig. 6**, http://links.lww.com/CCM/H577) (7, 12, 23, 24). Furthermore, POCUS-guided resuscitation may reduce the risk of AKI at 28 days, but the evidence remains uncertain (RR 0.71; 95% CI, 0.45–1.13; RD –11.8%, very low certainty; **eFig. 7**, http://links.lww.com/CCM/H577) (12, 19).

Organ Sustaining Therapies. POCUS-guided resuscitation may reduce the risk of receiving RRT at 28 days (RR 0.80; 95% CI, 0.63–1.02; RD –5.8%, low certainty; **eFig. 8**, http://links.lww.com/CCM/H577) (11, 16, 17, 19). However, there was an uncertain effect of POCUS-guided resuscitation on the duration of RRT (difference of 0.85 d less; 95% CI, 5.09 d fewer–3.40 d more, very low certainty; **eFig. 9**, http://links.lww.com/CCM/H577) (17, 19). We found no credible subgroup effect for the duration of RRT (eTable 4, http://links.lww.com/CCM/H577).

POCUS-guided resuscitation likely reduces the total duration of vasoactive medications by a difference of 0.73 d (95% CI, 1.16 fewer–0.30 fewer, moderate certainty; **eFig. 10**, http://links.lww.com/CCM/H577) (7, 9, 11, 16, 18, 19). POCUS-guided resuscitation probably results in little to no reduction in the provision of MV (RR 0.88; 95% CI, 0.67–1.15; RD –5.8%, moderate certainty; **eFig. 11**, http://links.lww.com/CCM/H577) (9, 18). For the duration of MV, we found the risk of bias, but not POCUS protocol, to be a highly credible subgroup that explained some of the heterogeneity seen between studies (eTable 4, http://links.lww.com/CCM/H577). However, important unexplained heterogeneity remained. Based on studies with a low risk of bias, the evidence is uncertain about the effect of POCUS-guided resuscitation on the duration of MV (0.19 d fewer; 95% CI, 0.96 fewer–0.58 more, very low certainty; **eFig. 12**, http://links.lww.com/CCM/H577) (9, 12, 13, 16, 17, 22).

ICU and Hospital Utilization. In a subset of patients presenting to the emergency department with shock,

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

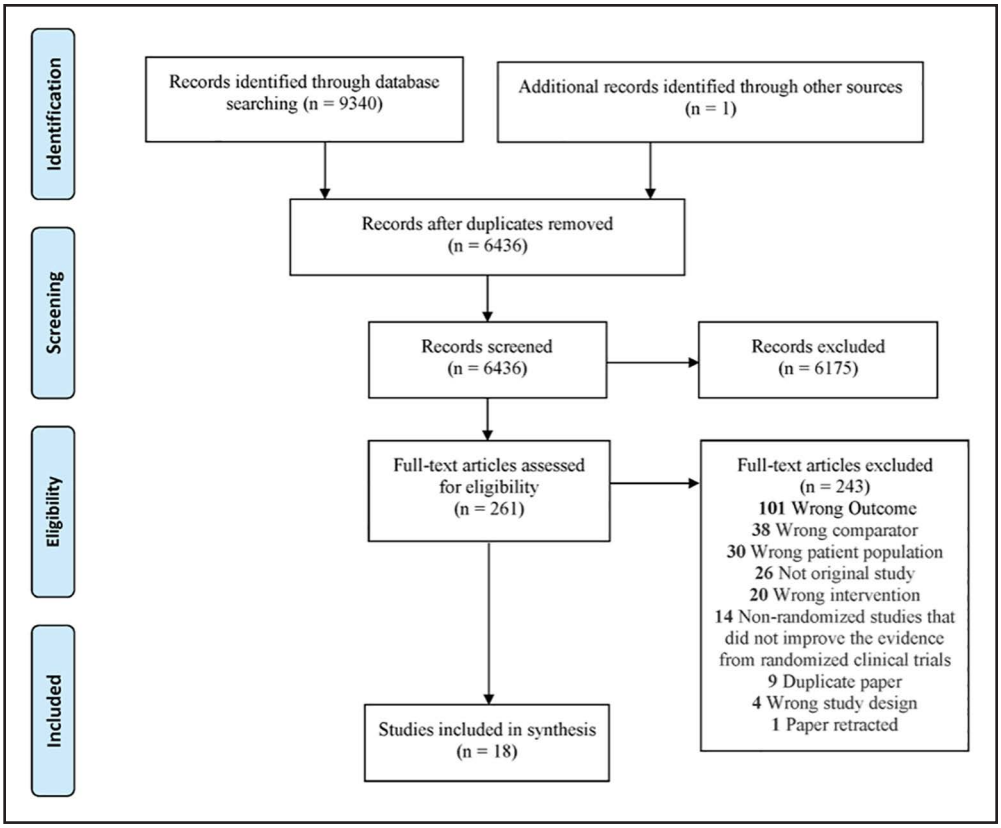
Identification
Screening
Eligibility
Included
Records identified through database searching (n = 9340)
Additional records identified through other sources (n = 1)
Records after duplicates removed (n = 6436)
Records screened (n = 6436)
Records excluded (n = 6175)
Full-text articles assessed for eligibility (n = 261)
Full-text articles excluded (n = 243)
101 Wrong Outcome
38 Wrong comparator
30 Wrong patient population
26 Not original study
20 Wrong intervention
14 Non-randomized studies that did not improve the evidence from randomized clinical trials
9 Duplicate paper
4 Wrong study design
1 Paper retracted
Studies included in synthesis (n = 18)

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

POCUS-guided resuscitation may result in little to no increase in ICU admissions (RR 1.28; 95% CI, 0.70–2.35; RD 3.3%, low certainty).

With respect to ICU length of stay, risk of bias, but not POCUS protocol, was a highly credible subgroup that explained some of the heterogeneity seen between studies (eTable 4, http://links.lww.com/CCM/H577). However, important unexplained heterogeneity remained. Based on the subset of low-risk bias studies, POCUS may result in no difference in the ICU length of stay (difference of 0 d; 95% CI, 1.00 fewer–0.99 more; low certainty; **eFig. 13**, http://links.lww.com/CCM/H577) (8, 9, 12, 13, 16, 17, 22).

Similarly, POCUS-guided resuscitation may not reduce hospital admissions (RR 0.98; 95% CI, 0.88–1.09; RD –1.8%, moderate certainty). For hospital length of stay, risk of bias, but not POCUS protocol, was a moderately credible subgroup (eTable 4, http://links.lww.com/CCM/H577). However, important unexplained heterogeneity remained. Based on studies with a low risk of bias, POCUS probably results in little to no difference in hospital length of stay (0.21 d fewer; 95% CI, 0.84 fewer–0.43 more, moderate certainty; **eFig. 14**, http://links.lww.com/CCM/H577) (8, 17, 18, 22, 23).

Mortality. POCUS-guided resuscitation probably reduces the risk of mortality (RR 0.88; 95% CI, 0.78–0.99; RD –4.3%, moderate certainty; **eFig. 15**, http://links.lww.com/CCM/H577) (7–19, 22, 23). Identified studies reported mortality at a timepoint of 28–30 days.

DISCUSSION

Main Findings

Based on this systematic review, POCUS probably influences physicians' decisions to administer IVF and prescribe vasoactive medication (Table 2), but these differences did not translate to large differences in IVF and inotrope administration. POCUS may reduce the number of diagnostic echocardiograms ordered by physicians (Table 3). Although the absolute difference of 9% may meaningfully reduce resource use and lead to cost savings, existing evidence comes from a single study that used a disposable TEE probe providing continuous monitoring. With respect to clinical outcomes, POCUS-guided resuscitation likely improves lactate clearance and reduces the duration of vasoactive medication, the need for renal replacement therapy, and 28-day mortality (Table 4). Furthermore, POCUS may reduce the risk of severe AKI (very low certainty evidence). We did not find evidence to suggest that POCUS-guided resuscitation impacts the need for and duration of MV and RRT, as well as the need for ICU and hospital admission and length of stay.

Strengths and Limitations

This is the first systematic review to comprehensively appraise POCUS across a hierarchy of outcomes specific to diagnostic technologies. We included a sensitive search strategy with no limitation on publication type and screening. To minimize bias and error, two

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

TABLE 2.

Grading of Recommendations Assessment, Development, and Evaluation Summary of Findings for the Impact of Point-of-Care Ultrasound on Changes in Physician Management

Outcome	Study Results and Measurements	Absolute Effect Estimates		Certainty of Evidence	Plain Language Summary
		Without POCUS-Guided Resuscitation	With POCUS-Guided Resuscitation		
Changes to IVF prescription	Based on data from 545 patients in 1 RCT	1.6 mean changes per patient	1.0 mean changes per patient Difference: 0.6 fewer management changes per patient (95% CI, 0.91 fewer–0.29 fewer)	Moderate (serious indirectness)	POCUS-guided resuscitation probably changes the IV fluid prescription slightly
Changes to inotrope medication prescription: inotrope initiation or dose escalation	Based on data from 545 patients in 1 RCT	0.7 mean changes per patient	0.3 mean changes per patient Difference: 0.4 fewer management changes per patient (95% CI, 0.54 fewer–0.26 fewer)	Moderate (serious indirectness)	POCUS-guided resuscitation probably slightly changes the initiation and escalation of inotropic agents
Changes to inotrope medication prescription: inotrope discontinuation or dose reduction	Based on data from 545 patients in 1 RCT	0.7 mean changes per patient	0.6 mean changes per patient Difference: 0.1 fewer management changes per patient (95% CI, 0.3 fewer–0.1 more)	Moderate (serious indirectness)	POCUS-guided resuscitation probably results in little to no difference in inotrope discontinuation or dose reduction
Changes to vasopressor medication prescription: vasopressor initiation or dose escalation	Based on data from 545 patients in 1 RCT	0.2 mean changes per patient	0.1 mean changes per patient Difference: 0.1 fewer management changes per patient (95% CI, 0.17 fewer–0.03 fewer)	Moderate (serious indirectness)	POCUS-guided resuscitation probably slightly changes the initiation or dose escalation of vasopressor medications slightly
Changes to vasopressor medication prescription: vasopressor discontinuation or dose reduction	Based on data from 545 patients in 1 RCT	0.5 mean changes per patient	0.4 mean changes per patient Difference: 0.1 fewer management changes per patient (95% CI, 0.25 fewer–0.05 more)	Moderate (serious indirectness)	POCUS-guided resuscitation probably results in little to no difference in vasopressor medication discontinuation or dose reduction

IVF = IV fluid, POCUS = point-of-care ultrasound, RCT = randomized controlled trial.

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

TABLE 3.

Grading of Recommendations Assessment, Development, and Evaluation Summary of findings for the Impact of Point-of-Care Ultrasound on Resuscitative Therapies And Diagnostic Tests

Outcome	Study Results and Measurements	Absolute Effect Estimates		Certainty of Evidence	Plain Language Summary
		Without POCUS-Guided Resuscitation	With POCUS-Guided Resuscitation		
Cumulative volume of IVF administered at 6 hr	Based on data from 918 patients in 7 RCTs	2.28L	1.89L Difference: 0.39 L less (95% CI, 0.65 L less–0.14 L less)	Low (serious inconsistency, serious imprecision)	POCUS-guided resuscitation may result in little to no reduction in the volume of IVF administered at 6 hr
Cumulative volume of IVF administered at 24 hr	Based on data from 935 patients in 11 RCTs	3.83L	3.21L Difference: 0.62 L less (95% CI, 0.89L less–0.35L less)	High	POCUS-guided resuscitation results in little to no difference the volume of IVF administered at 24 hr
Cumulative volume of IVF administered at 72 hr	Based on data from 775 patients in 3 RCTs	5.10L	4.91L Difference: 0.18 L less (95% CI, 0.68L–0.31 more)	Moderate (serious indirectness)	POCUS-guided resuscitation results in little to no difference the volume of IVF administered at 72 hr
Inotrope administration	RR: 0.99 (95% CI, 0.84–1.17) Based on data from 1128 patients in 6 RCTs	289/1000	289/1000 Difference: 3 less per 1000 (95% CI, 46 less–49 more)	High	POCUS-guided resuscitation results in little to no difference in the administration of inotropes
Diagnostic CT scans performed	RR: 1.10 (95% CI, 0.73–1.66) Based on data from 273 patients in 1 RCT	237/1000	261/1000 Difference: 24 more per 1000 (95% CI, 64 fewer–156 more)	Low (very serious imprecision)	POCUS-guided resuscitation may result in little to no difference in the number of diagnostic CT scans performed
Diagnostic transthoracic echocardiograms performed	RR: 0.74 (95% CI, 0.57–0.96) based on data from 545 patients in 1 RCT	354/1000	262/1000 Difference: 92 fewer per 1000 (95% CI, 152 fewer–14 fewer)	Moderate (serious indirectness)	POCUS-guided resuscitation probably reduces the number of diagnostic transthoracic echocardiograms performed

IVF = IV fluid, MV = mechanical ventilation, POCUS = point-of-care ultrasound, RCT = randomized controlled trial, RR = risk ratio, RRT = renal replacement therapy.

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

TABLE 4.

Grading of Recommendations Assessment, Development, and Evaluation Summary of Findings for the Impact of Point-of-Care Ultrasound on Clinical Outcomes

Outcome	Study Results and Measurements	Absolute Effect Estimates		Certainty of Evidence	Plain Language Summary
		Without POCUS-Guided Resuscitation	With POCUS-Guided Resuscitation		
Mortality at 28 d	RR: 0.88 (95% CI, 0.78–0.99) Based on data from 2163 patients in 17 RCTs	342/1000	297/1000 Difference: 41 fewer per 1000 (95% CI, 79 fewer–3 fewer)	Moderate (serious imprecision)	POCUS-guided resuscitation likely reduces mortality at 28 d
ICU admission	RR: 1.28 (95% CI, 0.70–2.35) Based on data from 273 patients in 1 RCT	119/1000	152/1000 Difference: 33 more per 1000 (95% CI, 36 fewer–160 more)	Low (very serious imprecision)	POCUS-guided resuscitation may result in little to no increase in ICU admissions
ICU length of stay	Based on data from 1037 patients in 7 RCTs	5.78 days	5.78 d Difference: 0 d fewer (95% CI, 1 fewer–0.99 more)	Low (serious inconsistency, serious imprecision)	POCUS-guided resuscitation may result in no reduction in the ICU length of stay
Hospital admission	RR: 0.98 (95% CI, 0.88–1.09) Based on data from 273 patients in 1 RCT	837/1000	820/1000 Difference: 17 fewer per 1000 (95% CI, 100 fewer–75 more)	Low (very serious imprecision)	POCUS-guided resuscitation may result in little to no reduction in hospital admission
Hospital length of stay	Based on data from 1160 patients in 5 RCTs	9.93 d	9.72 d Difference: 0.21 d fewer (95% CI, 0.84 fewer–0.43 more)	Moderate (serious inconsistency)	POCUS-guided resuscitation probably does not reduce hospital length of stay
Provision of MV	RR: 0.88 (95% CI, 0.67–1.15) Based on data from 311 patients in 2 RCTs	385/1000	338/1000 Difference: 46 fewer per 1000 (95% CI, 127 fewer–58 more)	Low (very serious imprecision)	POCUS may result in little to no reduction in the provision of MV
Duration of MV	Based on data from 1000 patients in 6 RCTs	3.85 days	3.66 d Difference: 0.19 d fewer (95% CI, 0.96 fewer–0.58 more)	Very Low (serious inconsistency, very serious imprecision)	The evidence is uncertain about the effect of POCUS-guided resuscitation on the duration of MV
Duration of vasoactive medications	Based on data from 449 patients in 5 RCTs	1.97	1.24 Difference: 0.73 d fewer (95% CI, 1.16 fewer–0.30 fewer)	Moderate (serious imprecision)	POCUS likely reduces the duration of vasoactive medications

(*Continued*)

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

TABLE 4. (*Continued*)

Grading of Recommendations Assessment, Development, and Evaluation Summary of Findings for the Impact of Point-of-Care Ultrasound on Clinical Outcomes

Outcome	Study Results and Measurements	Absolute Effect Estimates		Certainty of Evidence	Plain Language Summary
		Without POCUS-Guided Resuscitation	With POCUS-Guided Resuscitation		
Provision of RRT	RR: 0.80 (95% CI, 0.63–1.02) Based on data from 813 patients in 4 RCTs	254/1000	199/1000 Difference: 51 fewer per 1000 (95% CI, 97 fewer–8 more)	Low (serious indirectness, serious imprecision)	POCUS-guided resuscitation probably reduces the risk of receiving RRT
Duration of RRT	Based on data from 112 patients in 2 RCTs	4.63 d	3.78 d Difference: 0.85 d fewer (95% CI, 5.09 fewer–3.40 more)	Very Low (serious indirectness, serious inconsistency, very serious imprecision)	The evidence is uncertain about the effect of POCUS-guided resuscitation on the duration of RRT
Acute kidney injury at 28 d	RR: 0.71 (95% CI, 0.45–1.13) Based on data from 148 patients in 2 RCT	417/1000	296/1000 Difference: 121 fewer per 1000 (95% CI, 229 fewer–54 more)	Very Low (serious indirectness, very serious imprecision)	POCUS may reduce the risk of acute kidney injury at 28 d
Lactate clearance rate at 6 hr	Scale: Higher better Based on data from 621 patients in 6 RCTs	31.62%	36.55% Difference: 7.07% higher (95% CI, 0.13 higher–14.02 higher)	High	POCUS results in slightly greater lactate clearance at 24 hr
Lactate clearance rate at 24 hr	Scale: Higher better Based on data from 293 patients in 4 RCTs	32.83%	48.26% Difference: 15.40% higher (95% CI, 3.4 higher–27.4 higher)	High	POCUS results in slightly greater lactate clearance at 24 hr

MV = mechanical ventilation, POCUS = point-of-care ultrasound, RCT = randomized controlled trial, RR = risk ratio, RRT = renal replacement therapy.

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

authors independently conducted data extraction. We also comprehensively delineated the impact of POCUS with respect to changes in physician management decisions, whether patients ultimately receive interventions and diagnostic tests at relevant time points, and patient-important outcomes. We explored whether POCUS protocols demonstrated credible subgroup effects and undertook a systematic assessment of the certainty of evidence using GRADE methodology.

Our review has several limitations. First, the available evidence did not permit comparisons of POCUS-guided resuscitation based on the timing, frequency, and operator experience. Second, we could not investigate certain subgroup effects (e.g., patients with prior comorbidities such as heart failure were excluded in several studies). Third, some pooled estimates were limited by imprecision and low certainty of evidence. Fourth, except for a single study, all evidence came from single-center studies. Fifth, due to concerns with indirectness, we are limited in the conclusions regarding the impact of potential cost-savings due to POCUS.

Implications for Clinical Practice and Future Research

These findings present a compelling narrative where POCUS-guided resuscitation may improve patient-important outcomes, yet the precise mechanisms underpinning these improvements warrant further explanation. Perhaps due to increased confidence in decision-making, clinicians who used POCUS to guide resuscitation made fewer changes to IVF and vasoactive medication prescriptions. However, differences in the administration of IVF and inotropes were trivial between POCUS and control groups. One possible explanation is that the evolution of a patient's shock physiology could have prompted the clinician, given enough time, to implement the same management decisions regardless of whether POCUS was used. This may explain why POCUS resulted in slightly less IVF administered early in the resuscitation period (at 6 and 24 h), but differences abated at 72 hours. We speculate that POCUS may improve clinical outcomes by expediting resuscitative efforts. Improved lactate clearance and shorter duration of vasoactive medications, suggesting faster shock resolution, may support our speculation. Consequently, rapid reversal of shock physiology may explain why POCUS probably reduces injury to ischemia-prone organs, such as the kidneys, potentially reducing the need for RRT and mortality.

These findings raise important implications for research agendas with respect to the patient cohorts that might derive the most benefit. We have not yet determined whether certain patient phenotypes, such as those undifferentiated shock, mixed shock states, or those with comorbidities (e.g., cardiac dysfunction) that create narrow windows for optimal resuscitation, may experience more benefit from POCUS-guided resuscitation. These physiologic profiles, which often challenge clinicians with respect to timely diagnosis and competing resuscitation strategies, could better showcase the therapeutic potential of POCUS.

A lack of reporting on operator expertise, timing, and frequency of POCUS evaluations limits the generalizability of results. To better inform educational curricula and clinical practice guidelines, future research should investigate the minimum competency levels clinicians need and the optimal frequency and timing of POCUS evaluations.

Importantly, our review did not find any evidence of harm from using POCUS. For acute care settings where POCUS is already integrated for other purposes (e.g., procedural guidance), our results support the continued use of POCUS in guiding shock management. However, the decision to implement POCUS broadly, particularly in environments lacking the requisite infrastructure or training, necessitates a more cautious approach. We are unable to comment on the cost-effectiveness of POCUS in such contexts and call for ongoing evaluation of its utility and economic impact. Despite these considerations, the findings support the continued use of POCUS to guide the resuscitation of shock in certain acute care settings.

CONCLUSIONS

POCUS-guided resuscitation influences physicians' decisions regarding vasoactive medication and IVF administration, improves lactate clearance rate, and likely reduces the need for certain diagnostic tests (e.g., TTE), the duration of vasoactive medications, the need for RRT, and the risk of mortality. We require future studies to determine the minimum competency thresholds to derive clinical benefit, explore the cost-effectiveness of POCUS compared with other

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

hemodynamic guidance tools, and explore its impact on specific patient subgroups.

ACKNOWLEDGMENTS

The authors acknowledge Alla Iansavitchene for developing and refining the search strategy.

1 *Division of Critical Care, Department of Medicine, Schulich School of Medicine and Dentistry, Western University, London, ON, Canada.*

2 *Department of Critical Care Medicine, Faculty of Medicine and Dentistry, University of Alberta, and Alberta Health Services, Edmonton, AB, Canada.*

3 *Division of Critical Care, Department of Medicine, McMaster University, Hamilton, ON, Canada.*

4 *Department of Health Research Methods, Evidence, and Impact, McMaster University, Hamilton, ON, Canada.*

5 *Division of Critical Care, Department of Medicine, Mackenzie Health, Vaughan, ON, Canada.*

6 *Department of Anesthesiology and Perioperative Medicine, Mayo Clinic Florida, Rochester, MN.*

7 *Centro de Investigaciones Clínicas, Fundación Valle del Lili, Cali, Colombia.*

8 *Facultad de Ingeniería, Universidad Icesi, Cali, Colombia.*

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (http://journals.lww.com/ccmjournal).

Dr. Slessarev's institution received funding from the Canadian Institutes of Health Research (CIHR) project grant for randomized controlled trial related to ICU sedation; he received support for article research from the CIHR. The remaining authors have disclosed that they do not have any potential conflicts of interest.

For information regarding this article, E-mail: jbasmaji@uwo.ca

REFERENCES

1. Lipcsey M, Castegren M, Bellomo R: Hemodynamic management of septic shock. *Minerva Anestesiol* 2015; 81:1262–1272
2. Mayo PH, Beaulieu Y, Doelken P, et al: American College of Chest Physicians/La Société de Réanimation de Langue Française statement on competence in critical care ultrasonography. *Chest* 2009; 135:1050–1060
3. Guyatt GH, Tugwell PX, Feeny DH, et al: A framework for clinical evaluation of diagnostic technologies. *CMAJ* 1986; 134:587–594
4. Schandelmaier S, Briel M, Varadhan R, et al: Development of the instrument to assess the credibility of effect modification analyses (ICEMAN) in randomized controlled trials and meta-analyses. *CMAJ* 2020; 192:E901–E906
5. Higgins JPT, Savović J, Page MJ, et al: Chapter 8: Assessing risk of bias in a randomized trial. In: Cochrane Handbook for Systematic Reviews of Interventions, version 6.4 (updated August 2023). Higgins JPT, Thomas J, Chandler J, et al (Eds). Cochrane, 2023. Available at: www.training.cochrane.org/handbook. Accessed September 6, 2024
6. Guyatt G, Oxman AD, Akl EA, et al: GRADE guidelines: 1. Introduction-GRADE evidence profiles and summary of findings tables. *J Clin Epidemiol* 2011; 64:383–394
7. Alhabashy WS, Shalaby OM, Elgebaly AS, et al: Echocardiography-guided hemodynamic management of severe sepsis and septic shock in adults: A randomized controlled trial. *Anaesth Pain Intensive Care* 2021; 25:722–732
8. Atkinson PR, Milne J, Diegelmann L, et al: Does point-of-care ultrasonography improve clinical outcomes in emergency department patients with undifferentiated hypotension? An international randomized controlled trial from the SHoC-ED investigators. *Ann Emerg Med* 2018; 72:478–489
9. Elsayed AA, Elhamid Ahmed RA, Beshey BN: Early goal directed therapy versus a protocolized resuscitation care in early management of septic shock. *Egypt J Anaesth* 2022; 38:58–63
10. Garg M, Sen J, Goyal S, et al: Comparative evaluation of central venous pressure and sonographic inferior vena cava variability in assessing fluid responsiveness in septic shock. *Indian J Crit Care Med* 2016; 20:708–713
11. Gerges M, El-Azab A, Abdelaziz E, et al: Impact of shock multifocused ultrasound diagnostic protocol as routine screening at early intensive care stay on morbidity and mortality rates in shocked critically ill patients: A randomized controlled trial. *Crit Care Shock* 2023; 26:143–156
12. He Z, Yang X, Yang C, et al: Efficacy analysis of inferior vena cava variability combined with difference of central venous-to-arterial partial pressure of carbon dioxide on guiding fluid resuscitation in patients with septic shock. *Zhonghua Wei Zhong Bing Ji Jiu Yi Xue* 2022; 34:18–22
13. Ismail RM, Dahroug AH, Zaytoun TM: Determination of end point of fluid resuscitation using simplified lung ultrasound protocol in patients with septic shock. *Egypt J Chest Dis Tuberc* 2019; 68:102–107
14. Lanspa MJ, Burk RE, Wilson EL, et al: Echocardiogram-guided resuscitation versus early goal-directed therapy in the treatment of septic shock: A randomized, controlled, feasibility trial. *J Intensive Care* 2018; 6:1–8
15. Li G, Wei F, Zhang G, et al: Clinical value of early liquid resuscitation guided by passive leg-raising test combined with transthoracic echocardiography in patients with septic shock. *Zhonghua Wei Zhong Bing Ji Jiu Yi Xue* 2019; 31:413–417
16. Li L, Ai Y, Wang X, et al: Effect of focused cardiopulmonary ultrasonography on clinical outcome of septic shock: A randomized study. *J Int Med Res* 2021; 49:3000605211013176
17. Merz TM, Cioccari L, Frey PM, et al: Continual hemodynamic monitoring with a single-use transesophageal echocardiography probe in critically ill patients with shock: A randomized controlled clinical trial. *Intensive Care Med* 2019; 45:1093–1102
18. Musikatavorn K, Plitawanon P, Lumlertgul S, et al: Randomized controlled trial of ultrasound-guided fluid resuscitation of sepsis-induced hypoperfusion and septic shock. *West J Emerg Med* 2021; 22:369–378

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.

19. Qi B, Yang W, Zhang H, et al: Clinical application of inferior vena cava inspiratory collapsibility in early goal-directed therapy of septic shock. *Chin J Resp Crit Care Med* 2020; 19:246–250
20. Sricharoenchai T, Saisirivechakun P: Clinical outcomes of dynamic ultrasound-guided versus static central venous pressure-guided fluid resuscitation in patients with sepsis and/or septic shock in Thammasat University Hospital. In: *Intensive Care Medicine Experimental*. London, United Kingdom, Springer Nature, 2019, p 55
21. Wang X, Liu D, Zhang H, et al: Impact of extended focus assessed transthoracic echocardiography protocol in septic shock patients. *Zhonghua Yi xue Za Zhi* 2011; 91:1879–1883
22. Yin W, Qin Y, Zou T, et al: Critical care ultrasound oriented shock treatment in intensive care unit: A randomized controlled trial. 2021
23. Yu K, Zhang S, Chen N, et al; CCUGDT Study Group: Critical care ultrasound goal-directed versus early goal-directed therapy in septic shock. *Intensive Care Med* 2022; 48:121–123
24. Zhuang Y, Dai L, Cheng L, et al: Inferior vena cava diameter combined with lung ultrasound B-line score to guide fluid resuscitation in patients with septic shock. *Zhonghua Wei Zhong Bing Ji Jiu Yi Xue* 2020; 32:1356–1360

Downloaded from http://journals.lww.com/ccmjournal by BhDMf5ePHKav1zEoum1tQfN4a+kJLhEZgbsIHo4XMi0hCywCX1AWnYQp/IlQrHD3i3D0OdRyi7TvSFl4Cf3VC1y0abggQZXdtwnfKZBYtws= on 10/04/2024

Copyright © 2024 by the Society of Critical Care Medicine and Wolters Kluwer Health, Inc. All Rights Reserved.